

Navy Qualification Effort for HVOF Wear-Resistant Actuator Rod Coatings

Project Status as of 19 November 2003

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History of leakage related premature actuator removals prompted work in this area.

Initial efforts evaluated high temperature elastomer seals.

Lab endurance and in-service flight testing show performance of PTFE spring energized seals far superior to elastomer seals.

Laboratory testing showed super-finished HVOF coated rods have superior wear resistance compared to chrome plated rods.

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Although existing aircraft hydraulic systems are rated for 275°F, Buna-N seals accumulate damage above 160°F.

In 1996, several actuators were repacked with high temperature fluorocarbon rated for 350°F.

The repacked actuators were tested at elevated temperatures and static seals showed excellent performance, but some dynamic seals were damaged.

Canadian forces have flown a fluorocarbon equipped F/A-18 test aircraft since 1997 with no failures or measurable leakage.

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In 2000, several seal configurations were compared in high and low temperature endurance testing:

Baseline Buna-N and Improved Nitrile
Hydrogenated Nitrile,
Fluorocarbon and Fluorosilicon
and Spring Energized PTFE

Although better than Buna-N, all elastomer seals eventually showed degradation and leakage, some producing a tar-like contaminant (internal and external).

Spring energized PTFE seals showed superior performance and many had no measurable leakage or wear.

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6 layers of testing, 16 hours each layer.

Each hour consists of 20 minutes full stroke, 20 minutes of superimposed dither and 20 minutes of dither stroke.

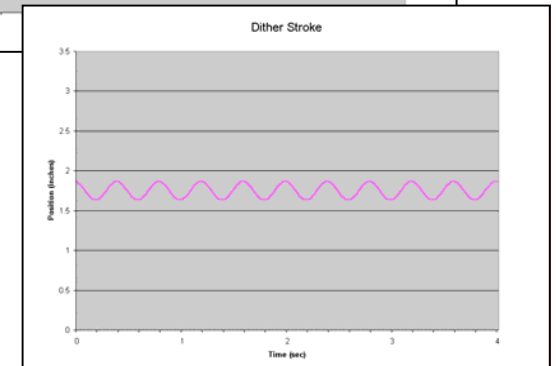
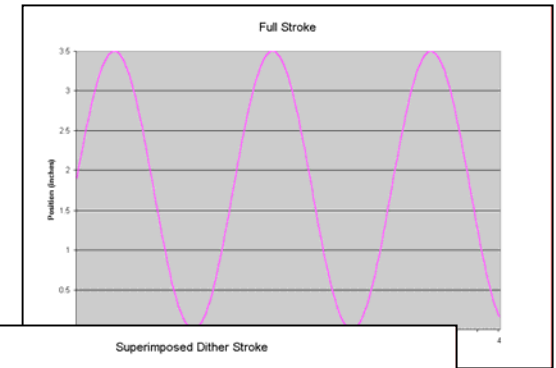
First layer is 160°F, second layer is 300°F, third layer is 275°F and temperature is reduced 25°F each subsequent layer.

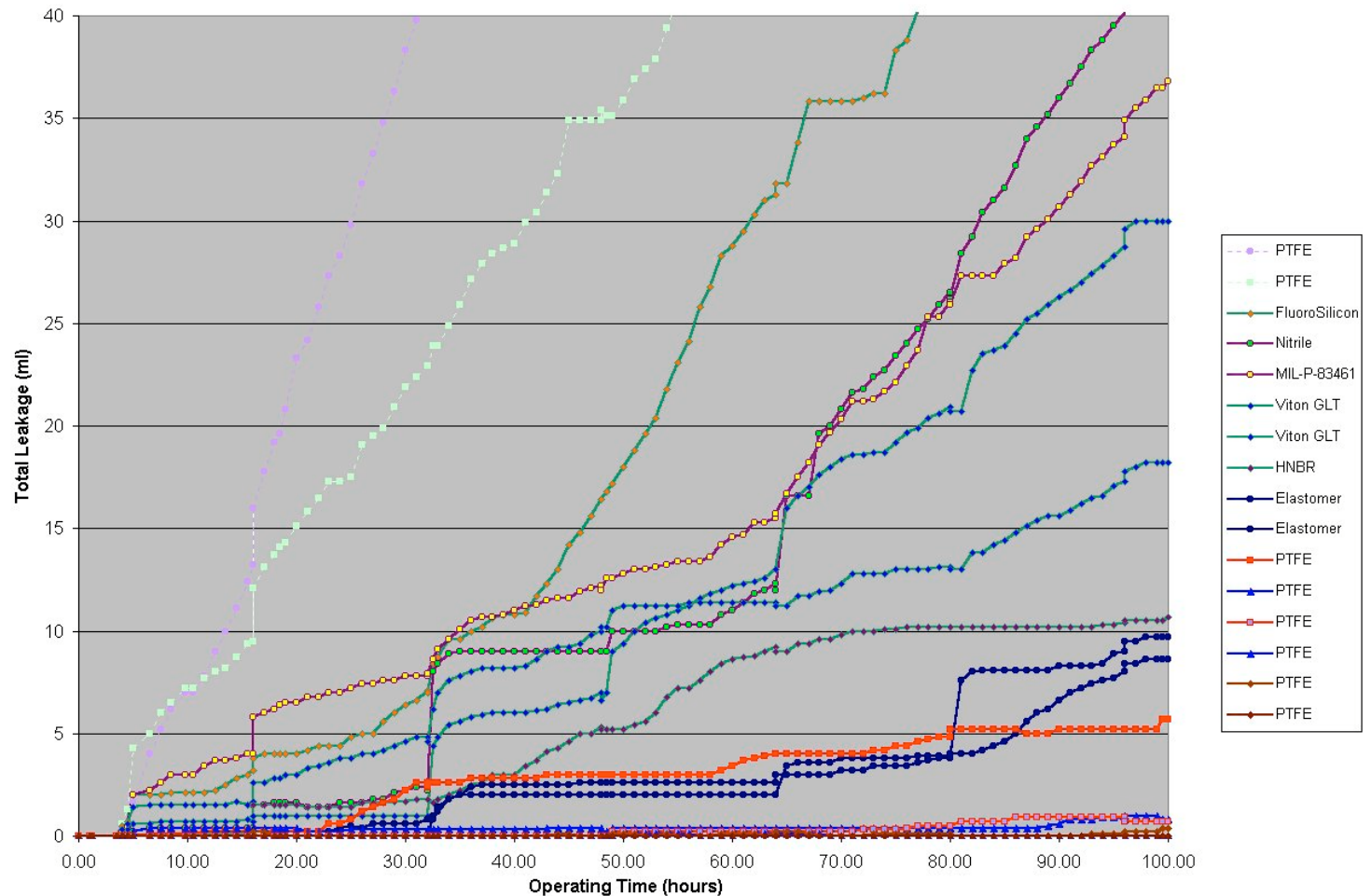
Seal blocks are chilled to 0°F each night to evaluate static leakage.

After layer 6, stand is cold soaked to -40°F and 4 hours of additional testing is performed to evaluate extreme low temperature and cumulative seal damage.

Total Time: 100 Hours

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2 seals leaked early on and continued steady leakage suggesting a design problem.

While excellent at high and low temperatures Fluorosilicon is easily damaged in a dynamic environment (not acceptable).

Nitrile and Improved Nitrile baseline seals have proven unacceptable in this test and in the field.

Engineered elastomers of Viton, HNBR all showed steady leakage with increased leakage during low temperature startup.

Elastomer degradation also produced a tar like sludge at the rod seal interface.

Several PTFE spring energized seals showed no measurable leakage through testing.



Once PTFE spring energized seals were selected, 4 different rod configurations were tested against the PTFE seals.



Coated Rod configuration:

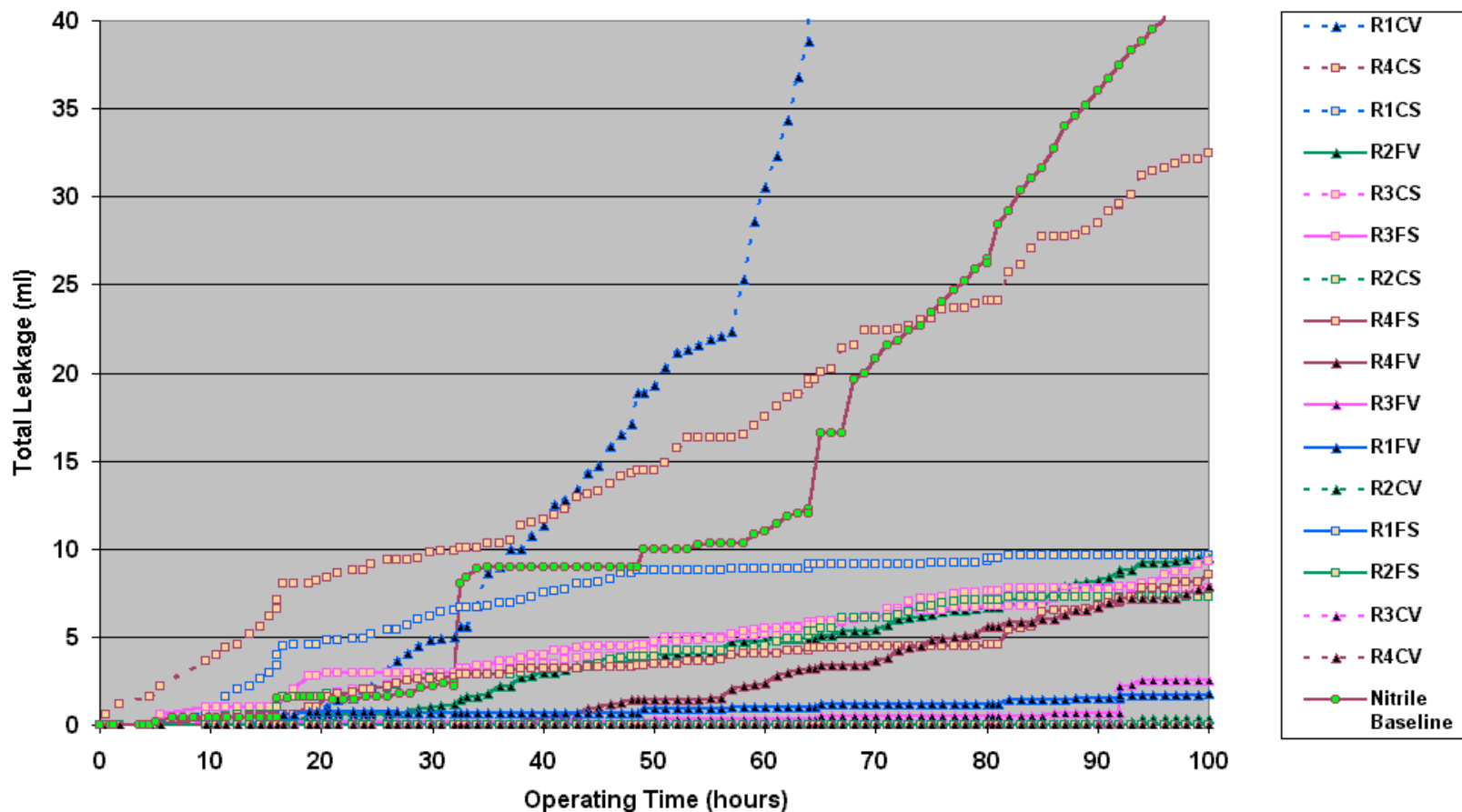
Rod #1 - WC/17Co

Rod #2 - WC/10Co4Cr

Rod #3 - WC/17Co (0.010" Thickness)

Rod #4 - Tribaloy 400





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Post-Test Observations

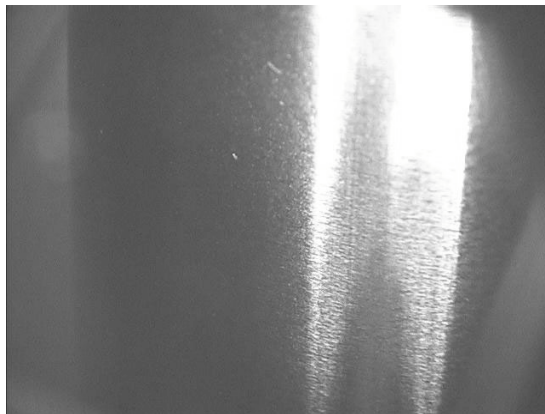
Chrome plated rods under these conditions developed longitudinal scratches, which is also a common problem on chrome plated rods on aircraft actuators.

Several programs report 25% as a typical requirement for chrome re-plating during overhaul.

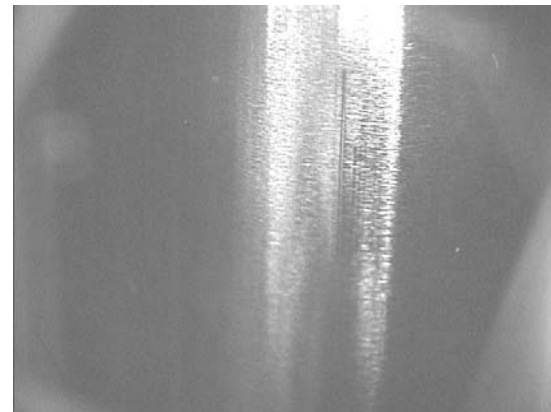
Inspection of HVOF rods showed wear marks and polishing but the accumulated surface damage was much less than with chrome plated test rods.

Initial surface finish is critical because wear resistant HVOF rods will not polish up in service.





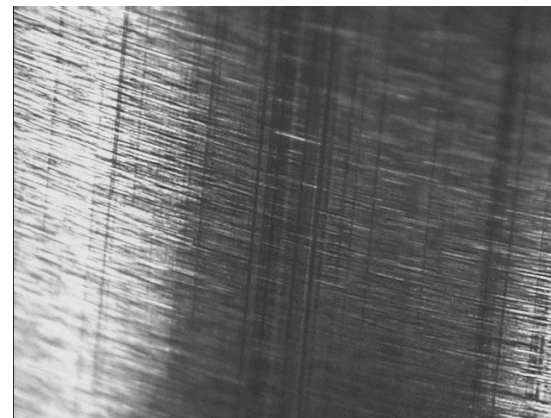
Pre-Test



Post-Test



100X



Axial scratching and galling after 100 hour endurance test

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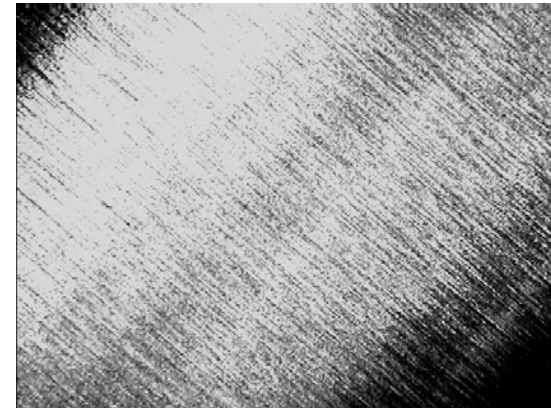
Pre-Test



Post-Test



100X



After 100 hour endurance test, no visible surface damage

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F/A-18 C/D Stabilator

History of significant reliability problems due to external leakage with actuators reworked every 6 months.

Based on laboratory results, fluorocarbon was selected for static seals and PTFE spring energized dynamic seals were selected for dynamic applications.

Rebuild kits for F/A-18 C/D stabilator actuator were developed by seal vendors using hardware dimensions.

Endurance testing of seal kits from three vendors showed excellent performance and post-test leakage within ATP limits.

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F/A-18 C/D Stabilator

Actuator reworked with AMS-R-83485 fluorocarbon static seals and PTFE dynamic seals tested to the following spectrum.

10 layers of testing.

Each hour consists of 3 minutes full stroke, 9 minutes of half stroke and 48 minutes of dither stroke

One layer at 275°F, two layers at 250°F, three layers at 225°F and four layers at 185°F.

Actuator was chilled to -40°F each night to evaluate static leakage.



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F/A-18 C/D Stabilator

| | | Max allowable | Saint Gobain | Greene Tweed | Shamban |
|---------------------------------------|----------------------|---------------|--------------|--------------|------------|
| @ Null Position in CAS mode | | | | | |
| | Sys 1 leakage | 0.90 gpm | 0.68 gpm | 0.55 gpm | 0.58 gpm |
| | Sys 2 leakage | 0.90 gpm | 0.59 gpm | 0.51 gpm | 0.54 gpm |
| @ Extend Position in CAS mode | | | | | |
| | Sys 1 leakage | 0.90 gpm | 0.51 gpm | 0.43 gpm | 0.41 gpm |
| | Sys 2 leakage | 0.90 gpm | 0.43 gpm | 0.41 gpm | 0.39 gpm |
| @ Retract Position in CAS mode | | | | | |
| | Sys 1 leakage | 0.90 gpm | 0.51 gpm | 0.54 gpm | 0.42 gpm |
| | Sys 2 leakage | 0.90 gpm | 0.45 gpm | 0.54 gpm | 0.41 gpm |
| @ Null Position in manual mode | | | | | |
| | Sys 1 leakage | 1135.0 ccpm | 813.6 ccpm | 375.3 ccpm | 800.4 ccpm |
| | Sys 2 leakage | 1135.0 ccpm | 631.5 ccpm | 366.1 ccpm | 624.1 ccpm |



F/A-18 C/D Stabilator

All vendors tested seals acceptable with no external leakage and acceptable internal leakage after endurance testing.

Follow-on testing evaluated HVOF coated rod against these seals.

Leakage performance was equivalent to chrome plated rod.

The leak-free actuator was boxed and shipped for tear-down inspection but was lost in shipping.

We plan to HVOF coat additional pistons for operational testing.

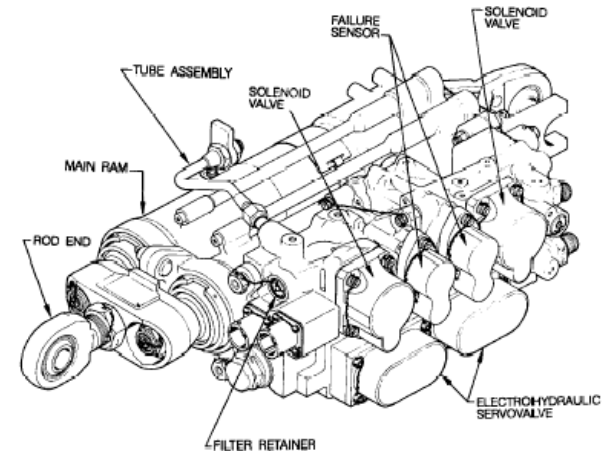
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F/A-18 C/D Trailing Edge Flap

History of significant leakage problems with actuators replaced every 6 months.

Fluorocarbon selected for static seals and PTFE spring energized dynamic seals selected for dynamic rod seals.



Side by side design allows one chrome rod and one HVOF rod to evaluate seals against both rod surfaces.

Endurance testing of first modified TEF actuator has been completed.

Pending successful lab testing, these modified actuators will be flown to evaluate in-service corrosion and wear resistance.

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P-3 Bombay Door Actuator

4 actuators with HVOF coated rods in service for ~2 years.

Actuators have accumulated >1000 flight hours.

Visual inspection shows no corrosion or external leakage.

Program is working to approve HVOF as an alternate repair procedure.



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H-60 Primary Flight Controls

Tri-Service initiative to upgrade seals and rod surfaces on primary flight control and tail rotor actuators.

High temperature elastomers (fluorocarbon or fluorosilicon) and PTFE dynamic seals are planned.

Rods will be coated with DOD defined HVOF coating on an attrition basis.

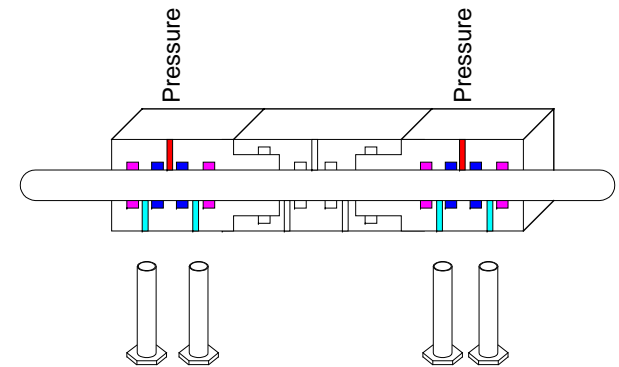
Parker is coordinating this upgrade across the entire customer base.

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Functional Rod/Seal Testing

Follow-on testing designed to optimize the HVOF application process will evaluate Improved Nitrile, Fluorosilicon and Spring Energized PTFE seals run against HVOF rods coated with slight process variations.



Additional rounds of testing will evaluate performance of other powder material alternatives.

Each test will run approximately 3 weeks with >1M strokes and 864,800 total inches traveled.

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Endurance and flight testing of improved seals and various wear resistant coatings for aging aircraft hydraulic and landing gear components.

Optimize HVOF process for repair of components and extend Navy Depot production capability.

Pending successful testing, authorize HVOF repair for similar applications on other hydraulic and landing gear components.

Investigate repair techniques for internal surfaces.

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